Relationships Between..

Climatic Factors and Yields of Cotton, Milo, and Kafir on Sandy Soils

in the Southern High Plains

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CONTENTS

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RELATIONSHIPS BETWEEN CLIMATIC FACTORS AND YIELDS OF COTTON, MILO, AND KAFIR ON SANDY SOILS IN THE SOUTHERN HIGH PLAINS

By W. C. Moldenhauer and F. E. Keating [1]

BACKGROUND OF THE STUDY

In areas of highly variable climate such as west-central Texas, it is difficult if not impossible to predict future climatic patterns even for short periods. As an average for the area, however, the winters are very dry; May and June are the months of highest rainfall; July is usually dry and followed by a period of rainfall in late August and early September. Successful crop production must fit this climatic pattern, and the crops grown must withstand long periods of summer drought.

Various workers, through correlation or regression analysis, have evaluated the importance of climatic factors in determining the variability of crop yields. Patton (6),[2] working with spring wheat in Montana, found high correlations between various individual climatic factors and yield. He obtained a correlation coefficient of 0.944 between relative humidity in June and July and yield of spring wheat. Staple and Lehane (9) calculated an evapotranspiration figure from the sum of stored moisture used from the soil plus the seasonal rainfall. They found this figure to be associated closely with yield of spring wheat. Smith (7), working in Louisiana, found a correlation coefficient of 0.755 between cotton yield and three variables--June rainfall, August rainfall, and August temperature.

This study was undertaken to obtain a better understanding of the effects of climatic factors on yields of cotton, milo, and kafir at Big Spring, Tex. It was hoped that information developed from this work would be useful in determining adapted cropping practices and land use in the Southern High Plains. The study included (1) correlations between climatic factors, (2) correlations of climatic factors with yields, (3) relationships between preseasonal precipitation and soil moisture, and (4) relationships between precipitation and yield.

PROCEDURE

Records from the Big Spring, Tex., Field Station from 1915 through 1954 were used in the study. Yield data were from 0.1-acre plots. For cotton, the yield data on Amarillo fine sandy loam were obtained from plots used in a 3-year rotation of cowpeas-milo-cotton because these plots were on Amarillo fine sandy loam that is typical for this soil on the station and were in a location where runoff water was not likely to collect. Keating and Mathews (5) found that cowpeas in the rotation had a very minor effect on cotton yield on these plots, especially since the forage was taken off as hay. For milo and kafir, the yield data on Amarillo fine sandy loam were obtained from a series of plots planted continuously to these crops. For cotton and milo, the yield data on Amarillo sandy clay loam were obtained from a 2-year cotton-milo rotation because the site of this rotation best typified this soil type.

The Amarillo fine sandy loam is a brown, fine sandy loam with a reddish brown, moderately permeable, sandy clay loam subsoil below the 10- to 18-inch depth. Free calcium carbonate occurs in the B horizon from 26 to 36 inches. Below this depth is the horizon of maximum calcium carbonate accumulation. The Amarillo sandy clay loam has been changed by erosion of fine material to a fine sandy loam at the surface. This is underlain by a reddish brown clay loam subsoil below the 8- to 14-inch depth. Traces of free calcium carbonate occur in the B horizon from 26 to 44 inches. Below this depth

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[2] Numbers in parentheses and underscored refer to Literature Cited, p. 10.

is the horizon of maximum calcium carbonate accumulation. This soil is similar to the Amarillo loam described by Carter et al. (2).

Climatic data were available from a weather station near the plot area. Average monthly maximum, minimum, and mean temperatures were obtained by averaging the maximum, minimum, and mean temperatures, respectively, recorded each day for the month. The daily mean was obtained from an average of the daily maximum and minimum temperatures. Maximum wind velocity used was the highest average recorded for a day during the month. Mean wind velocity was the average of 24-hour periods for the month. In the precipitation-soil-moisture study, amounts of soil moisture above the wilting percentage were considered to be available for plant growth.

Simple correlation coefficients were obtained according to the method of Snedecor (8), and multiple regression analyses were made following the methods outlined by Ezekial (3).

RESULTS

Correlations between climatic factors

Coefficients of correlation between various climatic factors are shown in table 1 and appendix table A. By way of explanation, factors that are associated are thought to be correlated. The correlation coefficient (r) expresses the intensity of the relationship. A correlation coefficient of 1.0 shows a perfect positive correlation; a coefficient of -1.0 shows a perfect negative correlation. Correlation coefficients of 0.8 or 0.9 are high and show that the factors measured are closely related. Coefficients of 0.3 or 0.4 are low and show much less association. High correlations mean more if a large number of observations are made. High correlation with 15 or less observations means less than the same correlation with 30 or more observations.

Highly significant negative correlations were obtained between annual and seasonal precipitation and temperatures in June, July, and August (table 1). Highly significant negative correlations were obtained between precipitation and temperature for each of these months individually. Correlation between preseasonal and seasonal precipitation was not significant.

Correlation between precipitation at various seasons and wind velocity was generally very low (appendix table A). The exception is the highly significant correlation between April precipitation and March maximum wind velocity. This association affects the only other significant correlation involving wind velocity--that between preseasonal precipitation (October 1 to April 30) and March maximum wind velocity. Correlations between April wind velocity and preseasonal precipitation (12 months prior to April 30) approach significance.

TABLE 1.--Coefficients of correlation between various climatic factors, Big Spring, Tex., 1916-54

Climatic factor	Precipitation							Temperature		
	Annual	Preseasonal	Seasonal	May	June	July	August	June mean	July minimum	August mean
Temperature:										
August mean	-0.604**	-0.398*	-0.553**	-0.190	-0.212	-0.162	-0.541**	0.326*	0.149	---
July mean	-.606**	-.270	-.681**	---	---	---	---	.425**	.767**	0.363*
July minimum	-.580**	-.360*	-.546**	-.102	-.310	-.449**	-.257	.362*	---	---
June mean	-.568**	-.323*	-.560**	-.377*	-.723**	.125	-.112	---	---	---
Precipitation:										
August	---	---	---	-.060	.006	.105	---	---	---	---
July	---	---	---	-.052	-.038	---	---	---	---	---
June	---	---	---	.023	---	---	---	---	---	---
Preseasonal (Sept 1-Apr. 30)	---	---	.205	---	---	---	---	---	---	---

* Significant at the 5-percent level.
** Significant at the 1-percent level.

Correlation of climatic factors with crop yields

Appendix table A shows the coefficients of simple correlation between yields of cotton and milo on Amarillo sandy clay loam and climatic factors including precipitation, temperature, and evaporation. The data used in these correlations were from 1915 through 1953.

For both cotton and milo, the correlation was higher between yield and annual precipitation calculated from September 1 to August 31 than from January 1 to December 31, or from October 1 to September 30. The highest correlated seasonal period for both crops was from April 1 to September 30 but for cotton the period from May 1 to August 31 was almost as high. The highest correlated preseasonal period for milo was from October 1 to April 30, and for cotton from September 1 to April 30. For milo, yields showed a significant correlation with precipitation by months in April, June, and August and for cotton, in August only.

Coefficients of correlation between yields of cotton and milo and mean temperature in June, July, and August were all negative and were all highly significant. For milo, the correlation was higher between yield and average mean temperature than average maximum or average minimum temperatures in June and July. In August, the correlations were the same for average mean and average maximum temperatures. For cotton, the highest correlation was with average mean temperature in June and August, but in July average minimum temperature was highest. In August, the correlations were practically the same for average maximum and average mean temperatures. For milo, the correlation with average minimum temperature in September was significant and positive.

For both crops, yield was significantly correlated with total evaporation in June and August, but not in July.

Preseasonal precipitation and soil moisture

The relationship between preseasonal precipitation and available soil moisture for the cotton crop is shown in figure 1 and for the kafir crop in figure 2. As preseasonal periods differed for cotton and kafir, the period September 1 to April 30 was used as the preseasonal period for kafir (fig. 2). Since most of the sampling was done about June 1, there was some overlapping of soil moisture and seasonal precipitation data for cotton. A great deal of this overlapping was compensated for by omitting soil-moisture values for the first foot of soil where the period September 1 to April 30 was used. Data used in determining these relationships are given in appendix tables B and C. In these studies moisture determinations used were from plots in milo continuously. Thus they are an index of moisture available for other crops and possibly do not represent normal values for cotton and kafir.

The formula for the relationship shown in figure 1 is

$$M_c = -0.59 + 0.163\ P_c,$$

where M_c is available soil moisture in inches about June 1 exclusive of the first foot of soil and P_c is the preseasonal precipitation in inches for the period September 1 to April 30. The correlation coefficient for this relationship was 0.825.

The formula for the relationship shown in figure 2 is

$$M_k = 0.126\ P_k,$$

where M_c is the available soil moisture in inches contained in the entire 6-foot profile and P_k is the preseasonal precipitation in inches for the period October 1 to May 31. The correlation coefficient for this relationship was 0.624.

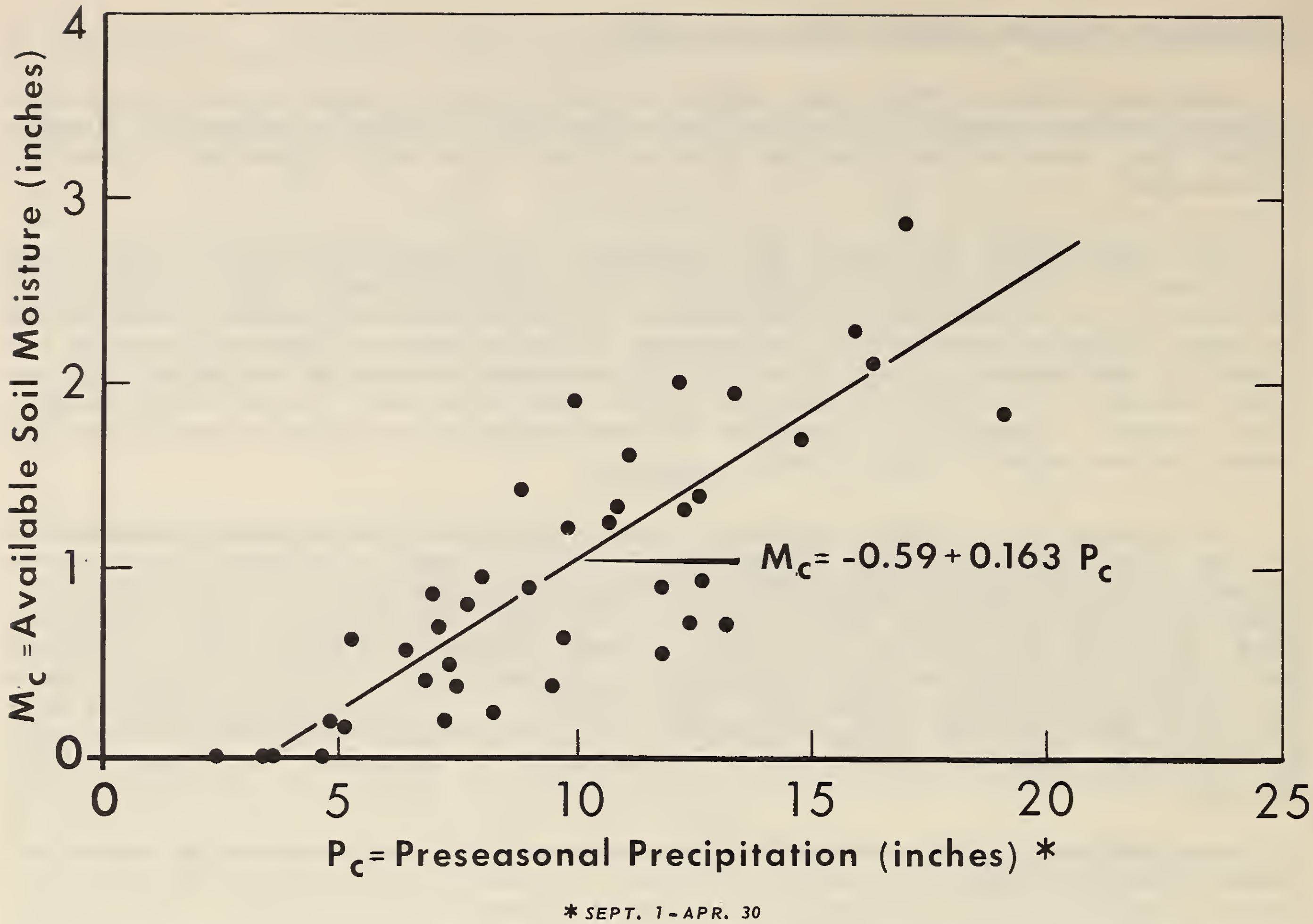

Figure 1.--Estimated soil moisture available for the cotton crop in relation to preseasonal precipitation, Big Spring, Tex., 1915-54.

Relationships between precipitation and yield

Coefficients of correlation between various periods of seasonal and preseasonal precipitation and yields of cotton and kafir on Amarillo fine sandy loam are shown in table 2. Data used in these correlations were from 1916 through 1954. Results for cotton in this table are very similar to those reported for cotton on Amarillo sandy clay loam in appendix table A. Coefficients of correlation between kafir yield and the periods of seasonal precipitation used are very similar (table 2).

Results of multiple regression analysis of yield of all the crops on preseasonal and seasonal precipitation are summarized in table 3. By way of explanation, regression shows how changes in one variable are dependent on changes in another variable. This dependence is measured by means of a regression coefficient (b), which shows the number of units the dependent variable will change, on the average, for a unit change in the independent variable.

The data in table 3 were for the period 1916 through 1954. To make the data comparable, the preseasonal periods were from September 1 to April 30 for cotton and from October 1 to May 31 for kafir and milo. Seasonal periods were from May 1 to August 31 for cotton and from June 1 to August 31 for kafir and milo. The annual period was from September 1 to August 31 for both cotton and kafir.

Average cotton yields on Amarillo sandy clay loam and on Amarillo fine sandy loam were 190 and 240 pounds per acre, respectively (appendix table B). As shown in table 3,

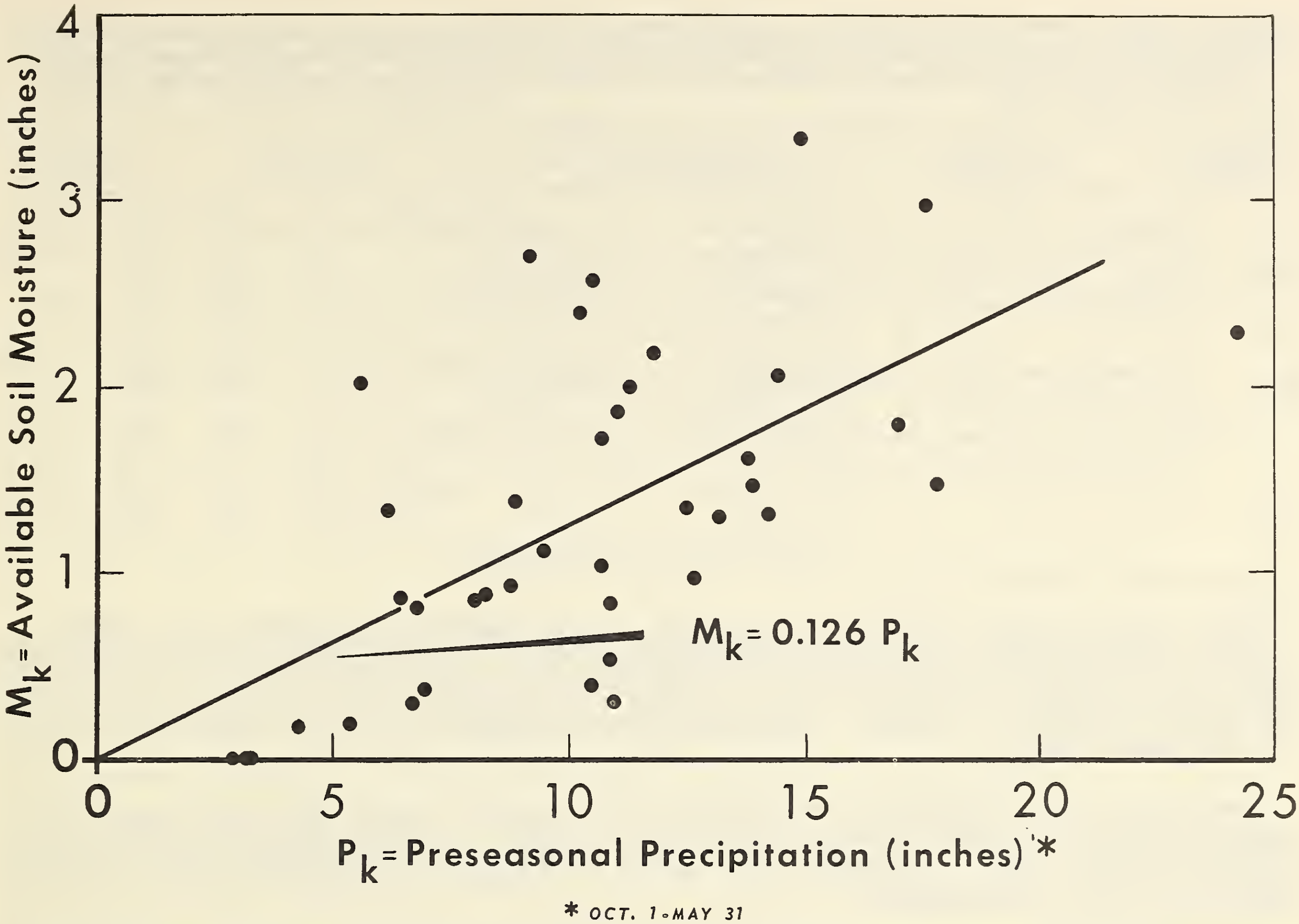

Figure 2.--Estimated soil moisture available for Kafir crop in relation to preseasonal precipitation, Big Spring, Tex., 1951-54.

TABLE 2.--Correlation between different periods of seasonal and preseasonal precipitation and yields of cotton and kafir on Amarillo fine sandy loam, Big Spring, Tex., 1916-54

Precipitation period	Correlation coefficient		Precipitation period	Correlation coefficient	
	Cotton yield	Kafir yield		Cotton yield	Kafir yield
Seasonal:			Preseasonal:		
May 1 to August 31.......	0.640**	0.643**	September 1 to April 30..	.489**	.437**
May 1 to September 30....	.566**	.625**	October 1 to April 30....	.361*	.469**
June 1 to August 31......	.459**	.645**	October 1 to May 31......	.565**	.526**
June 1 to September 30...	.424**	.623**			

* Significant at the 5-percent level.
** Significant at the 1-percent level.

the coefficients of correlation ($\underline{r}$) between cotton yield and preseasonal precipitation for the two soils were 0.550 and 0.489, respectively, and between cotton yield and seasonal precipitation, 0.612 and 0.640, respectively. Coefficients of multiple correlation were 0.745 and 0.733, respectively. Average milo yields on Amarillo sandy clay loam and on Amarillo fine sandy loam were 12.2 and 19.7 bushels per acre, respectively (appendix table C). As shown in table 3, the coefficients of correlation ($\underline{r}$) between milo yield and preseasonal precipitation for the two soils were 0.536 and 0.411, respectively, and between milo yield and seasonal precipitation 0.535 and 0.725, respectively. Coefficients of multiple correlation were 0.696 and 0.778, respectively.

TABLE 3.--Summary of results of multiple linear regression of yield on precipitation for cotton and milo grown on Amarillo sandy clay loam and for cotton, milo, and kafir grown on Amarillo fine sandy loam, Big Spring, Tex., 1916-54 [Coefficients of correlation (r, R), determination (R^2), standard regression (β), partial regression (b), and equation constant (a)]

Dependent (Yield)	Variable (Soil type)	Independent (Precipitation)	r	R	R^2	β	b	a
Cotton......	Amarillo sandy clay loam....	Preseasonal......	0.550**	0.745**	0.555	0.436	21.9	-57
		Seasonal.........	.612**	---	---	.515	15.0	---
	Amarillo fine sandy loam....	Preseasonal......	.489**	.733**	.537	.366	12.1	-29
		Seasonal.........	.640**	---	---	.537	18.2	---
Milo........	Amarillo sandy clay loam....	Preseasonal......	.536**	.696**	.485	.453	1.24	-9.8
		Seasonal.........	.535**	---	---	.452	1.58	---
	Amarillo fine sandy loam....	Preseasonal......	.411**	.778**	.605	.288	.89	-5.3
		Seasonal.........	.725**	---	---	.672	2.65	---
Kafir.......	............do.............	Preseasonal......	.526**	.763**	.583	.417	1.00	-3.1
		Seasonal.........	.645**	---	---	.564	1.75	---

** Significant at the 1-percent level.

For milo and kafir grown on Amarillo fine sandy loam, the coefficient of correlation between preseasonal precipitation and yield was 0.411 and 0.526, respectively (table 3). The coefficient of correlation between seasonal precipitation and yield was 0.725 for milo and 0.645 for kafir. Average yields were 19.7 bushels per acre for milo and 17.1 for kafir (appendix table C).

When years were omitted in which field notes indicated clearly that factors other than precipitation had reduced yields considerably (table 4), the coefficient of correlation between cotton yield (log values) and annual precipitation (log values) was 0.816. The formula for this relationship is

$$Y = 0.024\ A^{3.14},$$

where Y is the yield of lint cotton in pounds per acre, and A the annual precipitation from September 1 to August 31 in inches.

The coefficient of multiple correlation between yield (log values) and precipitation, preseasonal and seasonal, was 0.825. The formula for this relationship is

$$Y = 0.355\ P_c{}^{1.14} S_c{}^{1.86},$$

where Y is the yield of lint cotton in pounds per acre, P_c is the preseasonal precipitation from September 1 to April 30 in inches, and S_c is the seasonal precipitation from May 1 to August 31 in inches.

When the low-yield years 1923, 1929, and 1932 were omitted, the coefficient of correlation between kafir yield (log values) and annual precipitation (log values) was 0.789. The formula for this relationship is

$$Y_k = 0.031\ A^{2.12},$$

where Y_k is kafir yield in bushels per acre and A is the annual precipitation from September 1 to August 31 in inches.

When preseasonal and seasonal precipitation were considered as independent variables, the coefficient of multiple correlation was 0.834. The formula for this relationship is

$$Y_k = 0.211\ P_k{}^{1.24} S_k{}^{0.87}$$

where Y_k is kafir yield in bushels per acre, P_k is the preseasonal precipitation from October 1 to May 31 in inches, and S_k is the seasonal precipitation from June 1 to August 31 in inches.

TABLE 4.--Summary of results of multiple regression of yield on precipitation for cotton and kafir grown on Amarillo fine sandy loam (with years omitted when yield was affected by factors other than precipitation), Big Spring, Tex., 1916-54 [Coefficients of correlation (r, R), determination (R^2), standard regression (β), partial and net regression (b), and equation constant (a)]

Dependent (Log yield)	Variables (Soil type)	Independent (Log precipitation)	r	R	R^2	β	b	a
Cotton......	Amarillo fine sandy loam....	Annual...........	0.816**	---	---	---	3.14	-1.62
	........do..................	Preseasonal.......	.535**	0.825**	0.680	0.367	1.14	-.45
		Seasonal..........	.745**	---	---	.650	1.86	---
Kafir.......	........do..................	Annual...........	.789**	---	---	---	2.12	-1.51
	........do..................	Preseasonal.......	.662**	.834**	.695	.554	1.24	-.68
		Seasonal..........	.634**	---	---	.518	.87	---

Note: Years omitted for cotton: 1926, 1929, 1932, 1938, 1945, and 1948; for kafir: 1923, 1929, and 1932.

** Significant at the 1-percent level.

DISCUSSION OF RESULTS

Since temperature and precipitation are shown to be closely interrelated, it is doubtful that both should be used in determining the relationships between climate and yield. Rainfall figures can be used for any period without chance that one period will be closely related to another, whereas temperature figures for a particular period are affected by moisture conditions prior to as well as during the period. For this reason rainfall figures were used in multiple correlation and regression analyses in this study.

Coefficients of correlation between precipitation and wind velocity were generally too low to have much significance. The highly significant correlation between April precipitation and March maximum wind velocity was due apparently to one year (1922) when April precipitation was 12.77 inches (the average is 1.64 inches) and the average wind velocity for one 24-hour period in March was 23.4 miles per hour (the average is 12.3 miles per hour). If these values are left out, the correlation coefficient drops from 0.630 to 0.228.

For all crops, the correlation between yield and annual precipitation was higher for the period September 1 to August 31 than for any other period used. Correlation between yield and preseasonal precipitation, however, decreased for both milo and kafir when September values were included. This is presumably the result of the indefinite growing period of sorghum, and depends on weather conditions. When conditions are favorable during the summer, sorghum is ready for harvest in September. When conditions are unfavorable during the summer, it may continue growing in September. With milo the correlation decreases when October values are not included, as shown in appendix table A.

The highly significant coefficient of correlation between April precipitation and milo yield was used by Keating and Mathews (5) to explain the fact that fall plowing resulted in an increase in milo yield of only about 1 bushel per acre, on the average, over April 1 plowing. May 1 plowing, however, decreased the yield significantly below that of April 1 plowing.

The reason that the correlation was higher between cotton yield and July average minimum temperature than July average mean or maximum temperature is not known. The fact that total evaporation was correlated significantly with cotton yield in both June and August but not in July may be a result of the same phenomenon. Detailed information on the effect of temperature in relation to soil moisture is needed for an understanding of this phenomenon. The fact that the effect of temperature changes from negative in August to positive in September shows that cooler temperatures in September actually retard growth of cotton and milo.

Figures 1 and 2 show that the relationship between preseasonal precipitation and soil moisture is only fair. In figure 1, r^2 = 0.681, which leaves about 30 percent of the

variability in soil moisture unaccounted for by preseasonal precipitation. In figure 2, $r^2 = 0.389$, which leaves about 60 percent of the variability in soil moisture unaccounted for by preseasonal precipitation. When log values of soil moisture and preseasonal precipitation were used, an r^2 of 0.597 was obtained. This value was not significantly different from the values obtained with arithmetic values.

The data in appendix tables A and B indicate that in a number of years soil moisture was influenced by the amount of precipitation during the growing season of the previous year. Several attempts were made to account for some of the variability in soil moisture by taking this into account. No improvement resulted from these adjustments, and further examination of the data showed that in a number of years precipitation for the previous crop season had no effect on soil moisture at the June 1 sampling date. It was concluded that the variability in soil moisture unaccounted for by preseasonal precipitation was due in part to runoff, but perhaps also to a relationship with precipitation during the preceding growing season. This relationship is complicated by the amount of moisture used by the crop grown during the preceding season and will require more study before it will be useful in accounting for more of the variability in soil moisture.

The most striking difference observed between Amarillo sandy clay loam and Amarillo fine sandy loam was the difference in yield of both cotton and milo (appendix tables B and C). Yield differences were highly significant for both crops. Also for both crops, correlations between yield and preseasonal precipitation were higher on Amarillo sandy clay loam and correlations between yield and seasonal precipitation were higher on Amarillo fine sandy loam. The difference in correlation coefficients was more pronounced for milo than for cotton. This would be expected since the Amarillo sandy clay loam has a higher moisture-holding capacity than the Amarillo fine sandy loam and retains more of the preseasonal precipitation for use by the crops. On an even finer textured soil, Abilene clay loam, Burnett and Fisher (1) at Spur, Tex., obtained a correlation coefficient of 0.747 when cotton yields were correlated with available moisture in the second and third foot of soil.

Kafir has been thought to be more tolerant to drought than milo because of its indeterminate habit of growth (4) and because it does not tiller during periods of moist weather as does milo (4, 10). Appendix table C shows that range in yield from year to year on Amarillo fine sandy loam is not as great for kafir as for milo. Kafir yields were higher than milo yields in a few years, but ordinarily milo yields were higher. This is probably due to adaptability of individual varieties. Dwarf Yellow milo has always been the highest yielding grain sorghum variety at the Big Spring Field Station. It is now impracticable to grow, however, because it cannot be harvested with a combine. The coefficients of correlation (table 3) indicate that during wet seasons tillering of milo increases the yield considerably over that of kafir. Thus, the effect of seasonal precipitation is more important to milo yields than to kafir yields. Since kafir does not respond as much to high seasonal precipitation, preseasonal and seasonal precipitation are nearer to equal in importance.

The primary purpose of the fourth part of this study was to determine the relationship between precipitation and yield. It was believed that years in which yield was reduced considerably by factors other than precipitation would confuse the relationship. For this reason it was considered justifiable to omit them in this phase of the study. For example, cotton yields were reduced considerably in 1926 by leafhopper damage to squares, in 1929 and 1932 by late sandstorm damage, in 1938 by a heavy bollworm infestation, and in 1945 and 1948 by late planting and early frost.

Field notes were not maintained consistently on kafir, but it was noted that there was considerable damage from fall rains in 1923 and from late sandstorms in 1929 and 1932. It must be recognized that these hazards to crop production exist, and any calculation of risk involved in farming in this area must take these into account. It is interesting to note that the relationship between cotton yields and preseasonal and seasonal precipitation, when considered separately, were improved very little over that obtained with annual precipitation alone. The same was true for kafir. The relationship between annual precipitation and kafir yield would probably be improved if September values were omitted.

SUMMARY

Highly significant negative correlation coefficients were obtained between temperatures in June, July, and August and both annual and seasonal precipitation. Highly significant negative coefficients were obtained between temperature and precipitation in each of these months individually. Thus, low rainfall is shown to be associated with high temperature.

Correlations between wind velocity and precipitation were generally very low. There was a highly significant correlation between average maximum wind velocity in March and precipitation in April because of one year in which there was extreme wind velocity in March and eight times average rainfall in April.

For both cotton and milo, the correlation was higher between yield and annual precipitation calculated from September 1 to August 31 than from January 1 to December 31 or from October 1 to September 30. The difference was more pronounced for cotton than for milo.

Precipitation by months was significantly correlated with milo yield in April, June, and August but was significantly correlated with cotton yield only in August.

Average temperatures in June, July, and August were negatively correlated with yields of both cotton and milo. This negative correlation was highest in August for cotton but was very similar in all 3 months for milo. Thus, low temperatures are shown to be associated with high yields.

The coefficient of correlation between available soil moisture for the cotton crop in the 1- to 6-foot soil zone and preseasonal precipitation from September 1 to April 30 was 0.825. The coefficient of correlation between available soil moisture in the 6-foot profile and preseasonal precipitation from October 1 to May 31 was 0.624. When log values were used this coefficient was 0.773.

Average yield of cotton on Amarillo sandy clay loam and on Amarillo fine sandy loam was 190 pounds and 240 pounds per acre, respectively. The coefficient of correlation between preseasonal precipitation and yield of cotton was 0.550 and 0.489, respectively. The coefficient of correlation between seasonal precipitation and yield was 0.612 and 0.640, respectively.

Average yield of milo on Amarillo sandy clay loam and on Amarillo fine sandy loam was 12.2 and 19.7 bushels per acre, respectively. The coefficient of correlation between preseasonal precipitation and yield of milo was 0.536, and 0.411, respectively. The coefficient of correlation between seasonal precipitation and yield was 0.535 and 0.725, respectively.

Average yield of milo on Amarillo fine sandy loam was 19.7 bushels per acre compared to 17.1 bushels per acre for kafir. The coefficient of correlation between yield and preseasonal precipitation was 0.411 for milo and 0.526 for kafir. The coefficient of correlation between yield and seasonal precipitation was 0.725 for milo and 0.645 for kafir.

The formula for the relationship between cotton yield and annual precipitation (September 1 to August 31) was

$$Y_c = 0.024\ A^{3.14}$$

The coefficient of correlation for this relationship was 0.816. The formula for the relationship between cotton yield and preseasonal and seasonal precipitation was

$$Y_c = 0.355\ P_c^{1.14} S_c^{1.86}$$

The coefficient of multiple correlation for this relationship was 0.825.

The formula for the relationship between kafir yield and annual precipitation (September 1 to August 31) was

$$Y_k = 0.031\ A^{2.12}$$

The coefficient of correlation for this relationship was 0.789. The formula for the relationship between kafir yield and preseasonal and seasonal precipitation was

$$Y_k = 0.211\ P_k^{1.24} S_k^{0.87}$$

The coefficient of multiple correlation for this relationship was 0.834.

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APPENDIX

TABLE A.--Coefficients of simple correlation between climatic factors and yields of milo and cotton on Amarillo sandy clay loam and between precipitation and wind velocity, Big Spring, Tex., 1915-53

Climatic factor	Yield		Wind velocity			
			March		April	
	Milo Y_1	Cotton Y_2	Maximum Y_3	Mean Y_4	Maximum Y_5	Mean Y_6
Precipitation						
Annual:						
Jan. 1 to Dec. 31	0.618**	0.548**	0.137	0.064	0.145	-0.128
Oct. 1 to Sept. 30	.624**	.587**	.077	.031	.095	-.152
Sept. 1 to Aug. 31	.698**	.707**	---	---	---	---
Seasonal:						
May 1 to Aug. 31	.460**	.532**	---	---	---	---
May 1 to Sept. 30	.404**	.454**	---	---	---	---
Apr. 1 to Sept. 30	.568**	.545**	---	---	---	---
Preseasonal:						
Oct. 1 to Mar. 31	.468**	.432**	.065	.026	-.037	-.187
Oct. 1 to Apr. 30	.656**	.517**	.320*	.277	-.028	---
Sept. 1 to Mar. 31	.389*	.431**	-.124	---	---	---
Sept. 1 to Apr. 30	.630**	.572**	---	---	-.005	---
12 months prior to Apr. 30	.536**	.474**	.032	.000	-.252	-.298
Nov. 1 to Apr. 30	.641**	.433**	---	---	---	---
During previous growing season	.115	.149	---	---	---	---
April	.461**	.295	.630**	---	.030	.091
May	-.009	.185	---	---	---	---
June	.360*	.272	---	---	---	---
July	.194	.170	---	---	---	---
August	.400*	.438**	---	---	---	---
September	.098	.084	---	---	---	---
October	.244	.137	---	---	---	---
Temperature and evaporation						
May:						
Average maximum temperature	-.066	-.236	---	---	---	---
Average mean temperature	-.150	-.255	---	---	---	---
Average total evaporation	-.151	-.406*	---	---	---	---
June:						
Average maximum temperature	-.510**	-.410**	---	---	---	---
Average mean temperature	-.529**	-.468**	---	---	---	---
Average minimum temperature	-.329*	-.291	---	---	---	---
Average total evaporation	-.369*	-.328*	---	---	---	---
July:						
Average maximum temperature	-.343*	-.384*	---	---	---	---
Average mean temperature	-.506**	-.432**	---	---	---	---
Average minimum temperature	-.488**	-.504**	---	---	---	---
Average total evaporation	-.147	-.118	---	---	---	---
August:						
Average maximum temperature	-.541**	-.691**	---	---	---	---
Average mean temperature	-.541**	-.705**	---	---	---	---
Average minimum temperature	-.365*	-.522**	---	---	---	---
Average total evaporation	-.349*	-.560**	---	---	---	---
September:						
Average maximum temperature	-.045*	-.175	---	---	---	---
Average mean temperature	.129	-.002	---	---	---	---
Average minimum temperature	.355	.245	---	---	---	---
Average total evaporation	-.163	-.293	---	---	---	---

* Significant at the 5-percent level.
** Significant at the 1-percent level.

TABLE B.--Cotton yields and data used in determining yield, precipitation, and soil-moisture relationships, Big Spring, Tex., 1916-54

Year	Yield per acre		Precipitation			Soil moisture (excluding first foot)
	Amarillo fine sandy loam	Amarillo sandy clay loam	Annual (Sept. 1-Aug. 31)	Preseasonal (Sept. 1-Apr. 30)	Seasonal (May 1-Aug. 31)	
	Pounds	*Pounds*	*Inches*	*Inches*	*Inches*	*Inches*
1916	129	103	17.46	8.94	8.52	0.90
1917	0	8	7.05	4.66	2.49	0
1918	32	53	7.55	2.43	5.12	0
1919	467	365	25.11	10.85	14.26	1.34
1920	540	578	30.84	16.98	13.86	2.88
1921	198	110	15.23	7.47	7.76	.38
1922	232	243	21.75	15.90	5.85	2.29
1923	346	300	19.05	12.54	6.51	1.41
1924	187	133	18.43	11.77	6.66	.92
1925	403	224	14.13	6.86	7.27	.40
1926	232	175	22.00	11.77	10.23	.56
1927	194	95	18.25	13.15	5.10	.71
1928	410	251	22.07	6.47	15.60	.57
1929	95	110	15.82	7.03	8.79	.68
1930	220	163	18.82	12.36	6.46	.72
1931	209	194	17.39	12.62	4.77	.94
1932	360	290	33.88	19.15	14.71	1.85
1933	320	300	20.62	13.33	7.29	1.94
1934	178	188	12.23	6.97	5.26	.86
1935	394	337	20.22	7.22	13.00	.19
1936	119	92	17.08	11.10	5.98	1.63
1937	390	280	23.64	16.30	7.34	2.11
1938	254	213	24.23	9.78	14.45	1.23
1939	200	212	14.69	5.26	9.43	.62
1940	246	174	14.75	4.80	9.95	.19
1941	468	430	26.49	12.25	14.24	1.32
1942	220	180	24.25	12.16	12.09	2.01
1943	244	144	18.47	9.95	8.52	1.91
1944	229	154	15.58	8.20	7.38	.24
1945	280	240	26.82	9.68	17.14	.63
1946	234	110	11.50	7.32	4.18	.50
1947	240	180	15.46	8.79	6.67	1.42
1948	121	181	14.11	5.11	9.00	.16
1949	282	204	16.65	8.04	8.61	.96
1950	355	210	22.26	7.68	14.58	.81
1951	180	57	12.27	3.56	8.71	0
1952	0	0	5.58	3.34	2.24	0
1953	29	20	11.80	9.43	2.37	.37
1954	140	113	23.93	10.63	13.30	1.24
Average	240	190	18.40	9.53	8.86	0.94

TABLE C.--Kafir and milo yields and data used in determining yield, precipitation, and soil-moisture relationships, Big Spring, Tex., 1916-54

Year	Yield per acre			Precipitation		Soil moisture (6-foot profile)
	Kafir	Milo		Preseasonal (Oct. 1-May 31)	Seasonal (June 1-Aug.31)	
	Amarillo fine sandy loam	Amarillo fine sandy loam	Amarillo sandy clay loam			
	Bushels	*Bushels*	*Bushels*	*Inches*	*Inches*	*Inches*
1916	22.8	34.2	16.4	6.13	8.38	1.34
1917	.3	10.9	.3	4.30	1.88	.17
1918	0	0	0	2.83	3.93	0
1919	45.8	54.8	35.0	10.62	12.83	1.71
1920	27.5	31.6	38.3	14.87	8.54	3.32
1921	21.3	17.2	15.5	10.47	4.07	.39
1922	21.7	21.0	33.4	17.55	3.49	2.96
1923	13.2	20.5	29.7	13.78	5.27	1.61
1924	7.2	---	1.6	13.66	3.04	1.44
1925	12.7	8.6	9.1	8.27	5.18	.87
1926	21.7	14.0	5.7	10.67	8.27	1.03
1927	9.8	10.5	10.2	10.87	3.82	.83
1928	18.8	10.9	4.3	12.57	5.50	.97
1929	7.2	4.1	2.2	9.45	5.61	1.11
1930	8.2	7.8	1.6	8.87	4.51	1.37
1931	29.7	24.8	17.2	13.13	4.02	1.29
1932	31.5	31.6	20.2	24.28	9.53	2.28
1933	21.3	25.5	21.2	5.59	6.33	2.01
1934	15.0	21.4	7.9	6.41	5.18	.86
1935	17.2	23.8	10.3	10.91	8.40	.30
1936	18.2	11.0	.9	11.72	1.43	2.18
1937	20.0	25.5	10.9	9.14	3.98	2.69
1938	28.0	34.3	24.8	11.24	12.65	2.00
1939	28.3	23.3	6.9	8.05	6.53	.85
1940	21.3	8.3	3.6	6.62	8.13	.30
1941	32.5	49.7	43.6	16.95	9.35	1.79
1942	15.0	34.3	20.3	10.39	10.24	2.55
1943	13.8	19.5	10.9	10.13	4.08	2.39
1944	10.5	21.7	3.4	10.82	4.48	.52
1945	28.5	39.7	24.1	8.72	16.46	.92
1946	16.5	17.9	12.8	6.75	3.10	.80
1947	10.5	10.0	6.9	10.99	2.16	1.85
1948	10.5	12.6	1.0	5.35	8.06	.16
1949	17.7	16.2	7.6	12.44	4.19	1.34
1950	28.2	39.3	11.7	14.24	6.59	1.30
1951	6.0	6.6	.5	3.23	6.65	0
1952	0	0	---	3.16	1.42	0
1953	0	.2	1.9	6.92	1.66	.37
1954	7.7	13.6	3.3	17.73	5.65	1.46
Average	17.1	19.7	12.2	10.07	6.02	1.27

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